Remote mixed reality collaborative laboratory activities:

Learning activities within the InterReality Portal

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***Abstract*— Technology is changing our way to experience education from one-dimensional (physical) to multi-dimensional (physical and virtual) education using a diversity of resources such as web-based platforms (eLearning), videoconferences, eBooks and innovative technologies (e.g. mixed reality, virtual worlds, immersive technology, etc.). This represents bigger opportunities for universities and educational institutions to collaborate with partners from around the world and to be part of today's knowledge economy. This also enables greater opportunities to experience distance learning, modifying our experience of both space and time, changing specific spatial locations to ubiquitous locations and time as asynchronous/synchronous according to our necessities. The use of virtual and remote laboratory activities is an example of the application of some of these concepts. In this work-in-progress paper we propose a different approach to the integration of the physical and virtual world by creating remote mixed reality collaborative laboratory activities within an InterReality Portal learning environment, thereby extending our previous progress towards these goals. The learning goal of our mixed reality lab activity is to produce Internet-of-Things-based computer projects using combinations of Cross-Reality (xReality) and Virtual objects based on co-creative and collaborative interaction between geographically dispersed students.**

Keywords- Mixed reality; dual reality; xReality objects; blended reality; virtual laboratory; learning design; co-creative learning; constructionism; problem-based learning (PBL); immersive learning; interreality portal.

I. Introduction

Technology has been used in distance learning to develop tools and models to improve education for people in geographically dispersed locations. The use of different technologies, with different learning theories, has created innovative opportunities for new forms of educational laboratories which are different in nature to their traditional counterparts. Most research in this area has focused on extending instructional pedagogical practice in which lectures and theoretical knowledge are passed in a uni-directional manner from teachers to students, using the technology to create spaces and resources to that end. An alternative approach is the use of constructionist pedagogical practices whereby technology is used to create activities, settings and resources that encourages the learner to solve problems and construct their own knowledge by active thinking, and fosters a correlation between concepts and real tasks. Laboratory activities are based on this constructivist perspective. Experience in these activities is important as it provides the learners with an opportunity to test conceptual knowledge and to work collaboratively, interacting with equipment and performing analysis on experimental data. However, the use of network aware technology in distance learning, to support constructionist laboratory activities, is an area with many difficult challenges, involving the identification of different physical devices and diverse experimental equipment, the interfaces needed to complete a real physical experiment and diverse pedagogical challenges including the engagement between the learners and the technology, primarily focused on the feeling of increasing the sense of presence in the laboratory.

Some alternatives have been developed regarding these issues. One of these alternatives is the video recording of specific lab activities that can be accessed in an asynchronous way by learners. The benefit of this solution is the possibility to have the information in any time, everywhere but the lack of interaction with real equipment and the difficulty in carrying out collaborative work with other learners through the development of co-creative solutions to the problem presented has shown reduced user engagement [1] [2]. A second alternative is the use of remote laboratories where the experiment is implemented in a real setting and where the experimentation phases can be triggered only via software interfaces by distance learners [1] [3]. Finally a different solution is the implementation of virtual laboratories (eLabs) based on simulations using software interfaces [1] [2]. In both of these solutions similar problems are present as there is no interaction with real equipment and the activity is commonly performed with idealized data and subject to restricted collaboration [1].

Ma et al. [2] defined a four-dimensional goal model for laboratory education to measure competing technologies based on the premise that each technology has different learning objectives. The proposed laboratory goals are: conceptual understanding, design skills, social skills and professional skills. As an ideal model, real laboratory activities focus on these four learning objectives. Existing virtual and remote laboratories focus more on conceptual understanding and professional skills, although design skills have been considered by a few virtual laboratory projects. Thus *the effectiveness of laboratory work is seen to be correlated to the directness of its link to the real world* [2]. Two different aspects in the correlation with the real world were observed by Miller [2] [4]: the engineering fidelity which concentrates on how realistic the simulated environments are; and the psychological fidelity which can be the determining factor for the effectiveness of a virtual environment. Other studies [2] [5] confirmed that *despite a reduction in engineering fidelity; high psychological fidelity in virtual worlds can lead to a higher learning transfer*

[2]. Some comparative studies between remote and virtual laboratories have shown performance degradation in remote lab students is affected by the lack of physical presence (or realistic virtual presence) [6] [7]. Presence can be described as the *sense of being in a particular place* [2].

Immersive learning has the potential to promote solutions to the problems of presence in the use of remote/virtual labs [8] [9]. Immersive learning is the combination of diverse resources (interactive 3D graphics, commercial game and simulation technology, virtual reality, voice chat, webcams and rich digital media) with collaborative online course environments and classrooms. The benefit of this model is the sensation given to the learners of "being there", allowing them to participate and interact even when the participants are not in the same geographical place, enhancing the learning experience [10].

In this work-in-progress paper we explore the use and creation of remote mixed reality collaborative laboratory activities using an InterReality Portal, a holistic mixed-reality learning environment (Fig. 1). We begin by introducing the conceptual architecture and implementation of our work-in-progress test bed. Later in this paper we explain the conceptual model of cross-dimensional objects in order to create an Internet-of-Things collaborative lab project. Finally we explain different scenarios between the interaction of cross-dimensional and virtual objects and provide conclusions and challenges to be addressed in our future research.

II. THE INTERREALITY PORTAL

In previous work [11] [12] we presented an innovative mixed reality co-creative intelligent learning environment, the InterReality Portal, which is a collection of interrelated real and abstract devices comprising a 3D virtual environment, virtual and physical objects and software agents that allow users to complete activities at any point of Milgram’s Virtuality Continuum [13]. The Virtuality Continuum is a scale used to define the variations and compositions between reality and virtuality.

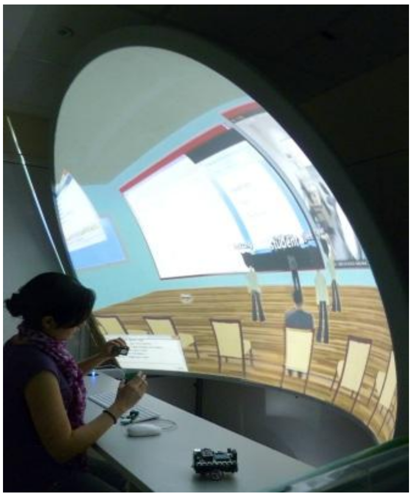

Figure 1. InterReality Portal

The objective of this learning environment is to allow students to collaborate together (constructing shared systems) using a mixture of real and virtual objects on a learning activity, based on creativity and collaborative learning [14] (co-creative process) applied to a mixed reality immersive environment to develop problem-solving skills with a social (team-work) dimension [15].

To interact between physical and virtual objects we defined two types of objects: xReality objects and virtual objects. xReality objects (Fig. 2) are formed by the physical object, one or more rules that determine the interaction with other objects, one or more behaviours which determine the interaction between the object and the 3D virtual environment, and the virtual representation of the object inside the 3D virtual environment. Virtual objects (Fig. 2) can only exist inside the 3D virtual environment although they have rules and behaviours associated [11].

To design the tasks and learning activities to be performed we use the Instructional Management Systems (IMS) Global Learning Consortium Learning Design specification [16]. The benefits of using this specification are: 1) the portability and reusability of the learning sessions, 2) the possibility to achieve particular goals regardless of the pedagogical methods utilised.

To work with the laboratory activities, our model applies problem-based learning (PBL), a constructionist student-centred method in which students can construct their own knowledge through the correlation between concepts and proposed solutions to real world problems performed in realistic settings [17].

A. Conceptual model

The mixed-reality immersive learning environment is formed by four layers. First the client layer where xReality objects are situated and where users interact with them, giving real-time information to the Data Acquisition layer. In this second layer the Context-awareness agent (*CAA*) first identifies the object being used in the learning task and then sends this information to the Mixed Reality (*MR*) agent in the following Event Processing layer. The *MR* agent obtains, from the Content Manager, a set of rules and behaviours available for the identified object. Finally the *MR* agent instantiates a virtual representation of the xReality object with its properties in the Virtualization layer. In the case of a virtual object the process is similar but excludes the client layer.

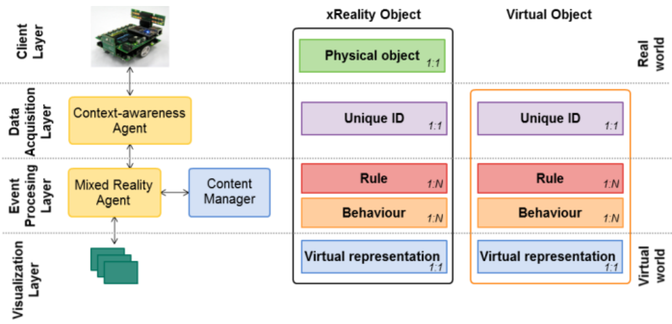

Figure 2. Conceptual Model

B. *Implementation*

The implementation of the InterReality Portal is based on 3 components:

a) A real environment: Formed by a semi-spherical sectioned screen the ImmersaStation manufactured from an Essex University specification [18] by Immersive Displays Ltd [1] (Fig. 1), a camera and some sensors and effectors allowing the automatic identification of actors and objects. A characteristic of this device is the similitude with a natural position for the student taking classes, sitting in a desk with a free-range of head movement without the need of any intrusive body instrumentation (e.g. special glasses) and not interfering with the immersive sensation.

b) A virtual learning environment developed at the University of Essex called MiRTLE project and based on Open Wonderland, a java-based open source toolkit for creating collaborative 3D virtual worlds [19]. MiRTLE links a physical classroom with a virtual classroom for remote learners, providing an instructional setting for teacher/student interaction [20] [21]. A benefit of using a virtual learning environment is that social interaction between remote users gives them a greater sense of presence and engagement within the class [8].

c) xReality objects and virtual objects: The interaction between physical and virtual elements within an environment can be defined as Cross-Reality (xReality) [22]. To create this xReality we utilise Fortito's Buzz-Board Educational Toolkit[2] which comprise 30 pluggable network-aware hardware boards that can be interconnected, and together with software modules can create a variety of Internet-of-Things (IoT) applications such as mobile robots, mp3 players, heart monitors, etc. [23] [24]. A particularly useful feature of these boards is that they use an internal network to signal what combinations of modules are plugged together (based on eventing that notifies of connections and disconnections). We are extending this notification to include software processes, threads and functions.

During this interaction, networked sensors obtain real-time information from xReality objects and send it to the 3D virtual environment. Once there, the data is processed to trigger events previously determined on the rules and behaviours associated to that particular xReality object. In a similar mode, interaction performed by virtual objects can be reflected into the physical world through diverse displays and actuators.

III. Co-creative Mixed Reality Learning Activities

The co-creative mixed reality learning activities are organized using Units of Learning (UoL), a structured sequence of activities that can be preceded by zero or more conditions before starting or completing the tasks [16]. This allows the learner to execute this sequence of actions to fulfil particular learning objectives. In the case of our virtual lab session the learning objective is to build a computer science project combining hardware (xReality objects) and software modules (virtual objects) creatively to implement Internet-of-Things (IoT) applications emphasising computing fundamentals.

To create this IoT application the students use the Deconstructed Appliance model to combine real and virtual components. In this model a number of elementary services (atomic functions) can be combined to create complex functions (nuclear functions) [25] [26].

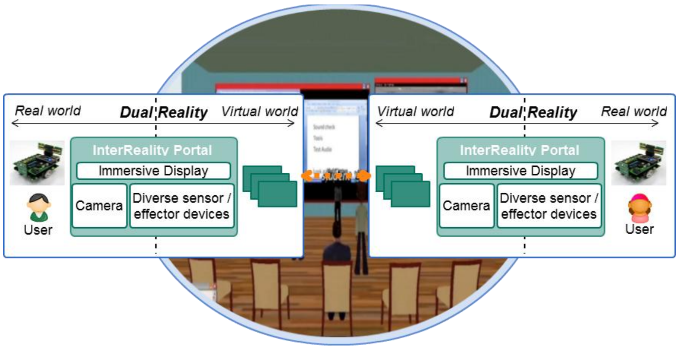

Figure 3. Multiple dual reality states.

The InterReality portal first identifies the object (xReality or virtual), actor and learning activity to be completed and perform the process described in section 2.A. In synchronism with this, the learning environment creates a single "*dual reality*" state. Lifton et al. defined *dual reality* as two worlds (one virtual and one real) that reflect, influence, and merge real-time information from each other by the use of sensor/actuator networks. *Both the real and virtual components of a dual reality are complete unto themselves, but are enriched by their mutual interaction* [27].

Blended Reality refers to the way that humans switch context between environments and blend traces of one into the other in a socially unconscious manner, often seemingly as simultaneously, thus avoiding the "*vacancy problem*" [28]. The "*vacancy problem*" is the capacity of user's presence and engagement to a single reality at a time. A user can be absorbed in a virtual reality, having a lack of presence in their local "reality" during this time and vice versa [29]. With Blended reality one person interacting in real-time with two different realities has the ability to extend them to work as if they were one. For collaborative activities in which two or more people share one common virtual world but different local realities and, possibly additional virtual environments, dual or not, interoperability becomes more complex. Applin at al. propose the term PolySocial Reality (PoSR) for this situation from the human interaction group perspective [30]. From the technological point of view a possible application of these ideas is the use of multiple dual realities using a physical and virtual space in group oriented synchronous time.

Thus after the establishment of a single *dual reality* state, the InterReality portal establishes communication with other remote learners. As long as the session continues, changes in any of the objects will be managed by the Context-Awareness agent and the Mixed Reality agent considering the following scenarios:

[1] Immersive Display Group - ImmersaStation http://www.immersivedisplay.co.uk/immersastation.php
[2] Fortito Educational Technology - http://www.fortito.com/buzz

a) A change in any Virtual object of a given InterReality Portal results in identical changes to all subscribing InterReality portals.

b) A change in an xReality object of a given InterReality Portal results in changes in the representation of the real device on all subscribing InterReality portals.

While this synchronization processes occurs our connected InterReality Portals extend the single *dual reality* state to a multiple *dual reality* state in which all virtual worlds views should be symphonised and synchronised with all the real worlds (Fig. 3).

A. Proposed architecture

Figure 4 illustrates the proposed architecture for our model. It is a form of client-server model where each InterReality Portal (a client) detects any change on the status of any object or actor via events in an UPnP network. This information is sent to the *Context-awareness* agent who identifies the object and the event. The *Mixed reality* agent sends the data to the web services layer in the server. This layer allows different client devices to interact with the environment through the World Wide Web. The changes captured in the client, once received by the server, will be executed in the 3D Virtual environment, which automatically will send a notification to all other clients subscribed to that particular virtual world. If the modification was executed in a virtual object, the server will update the object. If the modification was performed in an xReality object, the system will display a notification to the user explaining that a change has occurred and in order to synchronise the world it is necessary to do an action.

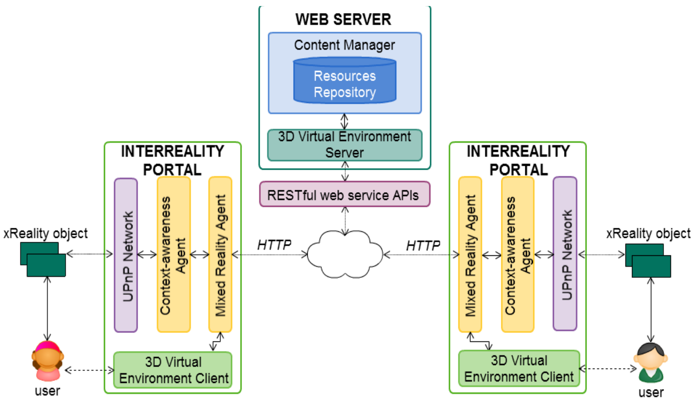

Figure 4. Model architecture

Summary and Future Directions

The main contribution of this paper is a computer architectural model for a novel co-constructionist mixed reality laboratory. Our model is unique in that it supports collaborative constructionist learning activities moving forward practice from the current one-dimensional instruction methodologies to multi-dimensions using xReality and Virtual objects creating a type of educational object designed that can be shared by teams of geographically dispersed students in a holistic immersive learning environment, the *InterReality Portal*. Additionally we justified this model and architecture by providing an extensive discussion based on published literature.

Also, we described how the combination of these objects and the designed learning activities defined for our test bed reflects the application of the concept of ‘Blended Reality’ to create multiple dual reality states, extending reality into virtuality to provide a learning environment and learning activities, based on constructivism and problem-based learning, to be executed as if they were performed in a traditional laboratory session.

Finally, this work-in-progress paper sets the basis for our upcoming research. At this stage we have defined a model and constructed the basic test-bed. Figure 5 summarises the implementation stages of our test bed. Phase 1 involves the construction of a fully functional InterReality Portal able to work with xReality and Virtual objects. Phase 2 explores the design and implementation of mixed reality laboratory activities using Learning Design UoLs, to evaluate the first scenario of our model; managing one dual reality state in a lab activity. Phase3 extends our research to the management of multiple dual reality stages between two or more InterReality Portals to create the blended reality while the learners perform the learning activity in separate locations as described previously.

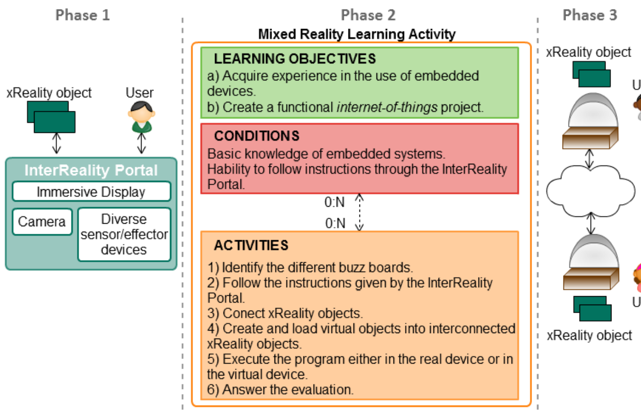

Figure 5. Implementation stages

Thus, in relation to this diagram, our research is moving from phase 1 to phase 2, integrating the InterReality Portal implementation with the learning design concepts, and as our work progress over the coming years we will gradually answer the various research questions set out in this paper, including addressing the technical issues in the management and creation of blended reality; to more pedagogical and educational concerns as it progresses, which we look forward to present in subsequent workshops and conferences.

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